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Involuntary autobiographical memories are relatively more often reported during high cognitive load tasks

Krystian Barzykowski*, Agnieszka Niedźwieńska

Applied Memory Research Laboratory, Institute of Psychology, Faculty of Philosophy, Jagiellonian University, ul. Ingardena 6, 30-060 Kraków, Poland

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ABSTRACT

Recent studies on involuntary autobiographical memories (IAMs) in daily life have shown that they are most frequently reported during daily routines (e.g. while ironing). Such studies have suggested that reporting IAMs may be influenced by the level of the ongoing task demands and availability of cognitive resources.

In two studies, we investigated the effects of cognitive load on reporting IAMs. To examine the presumed cognitive load dependency of IAMs, we utilised an often-employed experimental paradigm (Schlagman & Kvavilashvili, 2008) to elicit IAMs under conditions that differed in cognitive load. When performing a vigilance task, participants had to interrupt the task each time they experienced any spontaneous mental contents and write them down. We manipulated the level of cognitive load by either instructing (cognitive load group) or not instructing (control group) participants to perform an additional demanding task.

We compared the groups on the number of IAMs and other mental contents (non-IAM contents) recorded, as well as on the frequency of IAMs that was calculated as a proportion of IAMs in all mental contents reported by the participant. We expected that if reporting IAMs depends on the level of cognitive demands, then we should observe lower frequency of IAMs in the cognitive load group compared to the control group.

Consistently across studies, we observed a lower number of IAMs and non-IAM contents in the cognitive load group. However, IAMs unexpectedly constituted a higher percentage of all mental contents when participants were cognitively loaded. Further implications of the cognitive load effects for IAMs research and experimental methodology are discussed.

1. Introduction

Involuntary autobiographical memories (IAMs) come to mind without any conscious attempt at retrieval (Berntsen, 2010; Mace, 2007), and appear to be retrieved effortlessly in a non-strategic way (e.g. Uzer, Lee, & Brown, 2012). They are distinct from voluntary memories that are the result of an intention to retrieve a memory and typically, although not always (see Barzykowski & Staugaard, 2016, 2017; Uzer et al., 2012), involve an effortful search (Botzung, Denkova, Ciuciu, Scheiber, & Manning, 2008; Conway & Loveday, 2010).

While IAMs are presumed to be retrieved automatically, little is known about their accompanying cognitive mechanisms (e.g. cognitive load dependency). According to Berntsen (2009, p. 86), the question of how and why IAMs come to mind may be considered as one of the most intriguing issues in relation to understanding IAMs. Although there is a growing body of research concerning cognitive load and involuntary thoughts (e.g. Forster & Lavie, 2009; McKiernan, D'Angelo, Kaufman, & Binder, 2006; Smallwood, Nind, & O'Connor, 2009) or intrusive memories (e.g. Krans, Langner, Reinecke, & Pearson, 2013; Nixon, Nehmy, & Seymour, 2007), to the best of the authors' knowledge there are only two studies that addressed the cognitive load dependency of IAMs (Ball, 2007; Vannucci, Pelagatti, Hanczakowski, Mazzoni, & Paccani, 2015).

Extending knowledge about the cognitive mechanisms that underlie IAMs is an important step toward gaining insight into the nature and functioning of memory processes and human cognition. For example, involuntary memory processes may have a significant effect on emotion regulation (e.g. Gross, 2001), mood, and well-being (e.g. Kvavilashvili & Schlagman, 2011). They are also important in relation to identity (Rasmussen & Berntsen, 2009) and mental disorders, such as depression (Moulds & Krans, 2015; Watson, Berntsen, Kuyken, & Watkins, 2013) or PTSD (Berntsen, 2015). The empirical examination of IAMs under well-controlled experimental conditions may thus contribute to everyday life. The aim of the present study was to compare the frequency with which IAMs are reported during cognitively-demanding and cogni-

* Corresponding author.
E-mail address: krystian.barzykowski@uj.edu.pl (K. Barzykowski).

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tively-undemanding activities (Berntsen, 1998, 2009; Schlagman, Kvavilashvili, & Schultz, 2007).[1]

1.1. Cognitive load dependency of reporting involuntary autobiographical memories

Vannucci et al. (2015) pointed out that the issue of why IAMs come to mind pertains to a broader question; namely, given that IAMs occur automatically in response to incidental external and internal cues, why are we not constantly flooded by them in daily life? It is intriguing to ask what keeps these spontaneous memories at bay and enables us to carry on with our daily activities uninterrupted. The present paper aimed to verify one possible answer to this question; namely, that cognitive load related to many everyday activities may preclude reporting IAMs. IAMs should thus be reported more frequently in less cognitively-demanding conditions compared to more demanding conditions. This approach may be called the *cognitive load dependency view* (also *cognitive load hypothesis* by Vannucci et al., 2015). The results of existing studies on IAMs in which a naturalistic diary method was used (e.g. Berntsen, 1996) are in accordance with this view. They have shown that involuntary retrieval is more likely to be reported when attention is diffuse (Berntsen, 1996, 2009), and the individual is engaged in an automatic activity with low attention and cognitive resource demands (e.g. washing-up, walking, ironing). Also, results from studies on task-unrelated thoughts have shown that their frequency declines as cognitive load increases (McKiernan et al., 2006).

There may be several possible effects of cognitive load on the frequency of IAMs. Various effects may operate simultaneously, and thus the explanations proposed below are not mutually exclusive. First, Berntsen (2009, p. 97) suggested that IAMs may be generated through the same processes that are involved in monitoring and control of cognitively-demanding activities. IAMs and control mechanisms may thus compete for the same cognitive resources (see Mandler, 1994 for a similar argument). More specifically, Schlagman and colleagues proposed (Schlagman, Kliegel, Schulz, & Kvavilashvili, unpublished) that the ongoing activity that requires cognitive control reduces the frequency of IAMs by limiting the amount of working memory needed to process them. Second, Kvavilashvili and Mandler (2004) suggested that a diffuse state of attention induced by low cognitive load boosts the likelihood of processing cues that may act as potential triggers for IAMs, thereby enhancing spreading activation. Support to this idea comes from several studies that indicate that the retrieval of IAMs relies strongly on the priming and spreading activation mechanisms (e.g. Barzykowski & Niedźwieńska, 2017; Mace, 2005). Third, Baird and colleagues suggested (Baird, Smallwood, Fishman, Mrazek, & Schooler, 2013) that the participant's ability to monitor their flux of awareness and extract content of thoughts from the stream (including autobiographical contents) may be impaired by cognitively demanding tasks. Lending support to this suggestion, they found that cognitive load indeed undermined the ability to notice the content of thoughts. In a similar vein, a recently published study by Barzykowski and Staugaard (2017) suggests that any autobiographical memory needs to pass an awareness threshold to reach one's consciousness and this threshold may be modified by different factors. One of the factors is the expectation that a memory will occur which results in monitoring the stream of awareness more extensively. Barzykowski and Staugaard (2017) demonstrated (for similar results see also Barzykowski & Niedźwieńska, 2016; Vannucci, Batool, Pelagatti, & Mazzoni, 2014) that when an individual expects memories to occur and monitors the flux of thoughts more thoroughly, IAMs are more likely to be retrieved. Cognitive load related to the ongoing activity may be another factor that influences the awareness threshold. It contrast to the expectations that memories will appear, cognitive load should elevate the threshold. Whatever processes are actually induced by cognitive load, all the above explanations imply that reporting IAMs may be substantially limited by the high level of the ongoing task demands.

A definite test of the cognitive load dependency of reporting IAMs requires a study in which cognitive load is experimentally manipulated during the retrieval of IAMs. Ball (2007, Experiment 2) was the first who manipulated cognitive load in a laboratory setting. As he himself pointed out, the study was designed "to examine the role of attention in the elicitation of involuntary autobiographical memories by using the same word-association task under two different attention conditions" (Ball, 2007, p. 142).[2] He expected that if IAMs are more likely to be retrieved under low attention load, then they should be faster reported in that condition compared to a condition of high attention load. He found that involuntary memories were indeed more quickly elicited under the condition of low cognitive load. This finding lent first support to the notion that IAMs are affected by attention load. However, as Ball (2007, Experiment 2) measured only the speed with which IAMs were retrieved rather than the frequency of reporting them, his study did not directly address the aforementioned need of testing the cognitive load dependency of reporting IAMs.

A recent study by Vannucci et al. (2015) partially addressed the need of such test. They employed an often-used experimental procedure designed to elicit involuntary memories in the laboratory (Schlagman & Kvavilashvili, 2008). The procedure is a modification of the word-cue method (Crovitz & Schiffman, 1974), in which participants are exposed to short verbal phrases, some of which may incidentally trigger involuntary memories. Vannucci et al. (2015) experimentally manipulated the number of cues presented during the experimental session (i.e. the frequency/rate with which verbal cues were presented) and interpreted this manipulation as leading to different levels of cognitive load. As a result of the experimental manipulation, there were three conditions: (1) frequent cues (high cognitive load), (2) infrequent cues (low cognitive load), and (3) infrequent cues, but with additional tasks involving arithmetic operations (high cognitive load). As the authors expected, more IAMs were reported by the participants in the low cognitive load condition (infrequent cues) compared to the high cognitive load conditions (frequent cues and infrequent cues with arithmetic operations). Vannucci et al. (2015, p. 1082) interpreted these results as 'unequivocal support for the cognitive load hypothesis'. However, as their study "was designed to assess the effects of changing the cue frequency in the IAMs task" (Vannucci et al., 2015, p. 1079) rather than the effects of the direct manipulation of cognitive load, it can be argued that they provided only partial support for this hypothesis. As they manipulated the rate with which cues were presented, their findings are more open to explanations that are not related to cognitive load. For example, it may be speculated that slowing down the presentation of cues would render IAMs more likely because it would be easier for the participants to mentally time travel between different contexts and periods of time at a slower rate.

Therefore, the present study was designed to test the cognitive load dependency of IAMs in a manner that would overcome limitations of the interpretation of Vannucci et al. (2015) and Ball (2007, Experiment 2) findings. Most importantly, in order to directly manipulate cognitive

[1] Please note that it is unclear whether cognitive load may influence the retrieval of IAMs (e.g. forming and developing an involuntary autobiographical memory) or/and the ability to extract autobiographical content from the stream of consciousness and report it (i.e. post-retrieval processes). For this reason, throughout the present paper we decided to use the term 'reporting IAMs' to refer to giving a verbal (e.g. written or spoken) account of IAMs that one has experienced. The procedures employed in previous studies of IAMs (including the present study) do not allow us to unequivocally distinguish between the effects of cognitive load on the retrieval and post-retrieval processes (see the General Discussion section for a detailed explanation).

[2] The word-association tasks involves the experimenter presenting a word to the participant who must immediately provide the first thought that comes to mind associated with this word. Ball (2007) used the continuous word-association task that requires the participant to provide an initial association/response and then to continue giving a new association to each response that preceded it.

load we used an additional task that participants were or were not asked to perform (the cognitive load condition vs control condition). The task was entirely unrelated to cues that may have acted as potential triggers for IAMs. The use of the additional task enabled us to directly control and measure the presumed differences in the level of cognitive load between the conditions (see the next section for a more detailed explanation). Furthermore, in contrast to Ball's study, we measured the frequency of reporting IAMs rather than the speed with which were retrieved.

1.2. The present study

We utilised an often-employed experimental methodology that allows recording of IAMs under well-controlled conditions (Schlagman & Kvavilashvili, 2008). In the basic version of this procedure (see Barzykowski & Niedźwieńska, 2016, 2017; Barzykowski & Staugaard, 2016, 2017; Vannucci et al., 2014; Vannucci et al., 2015), participants are engaged in an uninteresting, undemanding vigilance task. During the task they are exposed to short verbal phrases, some of which may incidentally trigger thoughts. Participants are instructed to write down any mental contents that spontaneously occur during the vigilance task. They have to interrupt the vigilance task every time they want to write down such a thought. Finally, at the completion of the task, participants are given their thought descriptions and asked to indicate which of them were memories. The most substantial difference between the basic procedure of capturing IAMs in the laboratory and the current procedure was that, on each trial, we additionally displayed a square with a random number in it. By instructing half the participants to perform an additional task related to numbers displayed in squares, we were able to directly manipulate the level of cognitive load between participants. According to the cognitive load dependency view, the frequency of IAMs should be influenced by an additional task, and thus we should expect less frequent IAMs in the cognitive load condition (with the additional task) compared to the control condition (without the additional task). Alternatively, if IAMs arise automatically at minimal cognitive cost, the cognitive load condition and the control condition should not differ in the frequency of IAMs.

In contrast to Vannucci et al. (2015), we were able to measure the level of performance on the additional task to control for the extent to which participants were actually engaged in performing it. Therefore, we were able to examine whether their engagement was high enough to increase cognitive load. Although Vannucci et al. exposed participants to simple arithmetic operations (e.g. 3 + 8 = 11) in one condition, participants were told not to perform these operations. Vannucci et al. (2015) assumed that participants would automatically read these formulas, as typically happens with verbal cues, and would episodically check their validity, thereby increasing cognitive load. While we may agree with this reasoning, it is unknown to what extent participants were indeed checking the validity of the arithmetic operations. In addition, we compared the conditions with and without the additional task in terms of how participants perceived the task difficulty. Therefore, we were able to examine whether the presumed differences in the level of cognitive load between the conditions were reflected in subjective ratings.

There was also a need to control for some other differences due to the experimental between-subjects manipulation. It is worth asking what a difference in the number of IAMs actually tells us about their underlying processes. This question is especially important in relation to the use of a dual-task paradigm. For example, the cognitive load manipulation usually requires performing an additional, relatively demanding task which may strongly influence the amount of time participants have for reporting any spontaneous thoughts or memories. As participants in the control group do not have to spend time performing the second task, they may simply have more time to write down their thoughts. In contrast, the individuals in the cognitive load group are able to either perform the second task or to report thoughts at a given time. Also, being busy with the additional task may result in participants paying less attention to verbal phrases presented on the screen, and thus being overall less exposed to such phrases compared to participants in the control condition.

Both of these scenarios (i.e., having less time to write down spontaneous thoughts, and paying less attention to verbal cues) may significantly contribute to the decrease in the number of IAMs (and other mental contents) reported in the cognitive load condition compared to the control condition. In other words, the differences in the number of reported IAMs between conditions may reflect not only the presumed cognitive load dependency of IAMs but also those differences between conditions that result from the specific experimental context related to a dual-task paradigm. In order to minimize this risk, we calculated an *involuntary autobiographical memory density index* (henceforth called an IAMD index). We propose this index to be a measure of the proportion of involuntary autobiographical memories to the total number of all mental contents reported by a given individual. The higher the IAMD index, the higher the proportion of memories in all reported mental contents. IAMD index indicates the frequency of IAMs. For example, an IAMD index of 0.40 means that 40% of all mental contents reported by the participant were IAMs. The IAMD index can be the same for two participants who recorded a different number of IAMs because it takes into account the participants' cognitive activity as a whole and the specific experimental context related to a dual-task paradigm, i.e. having more or less time to write down spontaneous thoughts and more or less chance to notice thought triggers. The presumed cognitive load dependency of reporting IAMs predicts lower IAMD index in the cognitive load condition compared to the control condition. Alternatively, if reporting IAMs occurs automatically at minimal cognitive cost, then we should not observe differences between the control group and the cognitively-loaded group on the IAMD index.

In addition, to evaluate the comparability of participants across the experimental conditions, we asked a series of control questions both online, while participants were performing the vigilance task, and after completion of the vigilance task. The control questions served to investigate whether the conditions with and without the additional task were equivalent in terms of how participants perceived the importance of the experimental task, how much they concentrated on the task and the verbal cues presented on the screen, and how important it was for them to perform the task well. The online questioning procedure was deliberately brief in order not to interfere with either the main vigilance task or the stream of consciousness.

2. Study 1

The Research Ethics Committee approved the usage of the modified version of the experimental method developed by Schlagman and Kvavilashvili (2008). Written consent for participation was obtained prior to data collection.

2.1. Participants

A total of 61 undergraduate students were recruited and randomly assigned to the two experimental conditions: the cognitive load condition and control condition. They were all screened for depression using the Polish version of the Beck Depression Inventory (Parnowski & Jermajczyk, 1977). Six participants who scored 20 or above were excluded from the sample.[3] Therefore, the final sample consisted of 30 participants in the cognitive load condition (18 females, M_{age} = 22.25, SD = 1.96, range 20–27 years) and 25 participants in the control condition (17 females, M_{age} = 23.04, SD = 2.36, range 19–32 years). Students participated in return for a gift card worth around $5 USD.

[3] Since IAMs may be related to various mental disorders, for example depression (Moulds & Krans, 2015; Watson et al., 2013), we wanted to control for this factor.

2.2. Materials

2.2.1. Involuntary Memories Program (IMP)

The experiment employed a modified and fully computerized method that had been originally developed by Schlagman and Kvavilashvili (2008). The Involuntary Memories Program (IMP) is described elsewhere in more detail (Barzykowski & Niedźwieńska, 2016, pp. 5–6; also Barzykowski & Staugaard, 2016, p. 524). Briefly, it consists of three main consecutive parts: (1) an introduction that provides participants with detailed written instructions accompanied by examples of the line patterns; the introduction consists of two trial sessions, (2) the spontaneous thought reports taken during a main vigilance task, and (3) the autobiographical memory selection during which participants are asked to decide whether the thoughts that they reported in part 2 were autobiographical memories.

In general, participants performed a monotonous vigilance task that involved detecting a pattern of 15 vertical lines in a stream of 785 horizontal lines, with each set of lines presented for 2 s during each separate trial. Each set consisted of four to ten lines in which two to eight lines were in a blue colour while the rest were in black. In addition, short verbal phrases (e.g. *riding a bicycle*, *listening to the radio*) were displayed on each trial in the centre of the screen. The final pool of 800 phrases consisted of an approximately equal numbers of carefully selected neutral ($N = 267$), positive ($N = 267$), and negative ($N = 266$) phrases.[4] There was also a square (approximately 1.5 cm by 1.5 cm) below each phrase with a random number displayed in the middle (ranging from 1 to 9). The number and colour of the square changed randomly with each slide (colours used: black, green, blue, orange).

Participants first completed two practice sessions that consisted of 25 cards each. Only one pattern of vertical lines was presented in each session and verbal phrases were displayed in the same fixed order for each participant. Following these practice trials, the main vigilance task began that consisted of 800 cards randomly generated for each participant.

2.3. Procedure

Participants were tested in groups of 2 to 6. They were informed that they were free to withdraw from the study at any point. The experimenter assured them that their responses would be anonymous and they could refrain from reporting particularly sensitive thoughts by typing “X” as an answer, or (if possible) by providing a general description of their thoughts rather than a detailed account. In order to minimize intentionality during retrieval (Barzykowski, 2014; Barzykowski & Niedźwieńska, 2016; Vannucci et al., 2014) and to maximize involuntary retrieval (Barzykowski & Staugaard, 2016), participants were instructed to report any spontaneously occurring thoughts rather than memories only. At the beginning of the session, the experimenter only briefly introduced the participants to the procedure. They then started the IMP which provided them with more detailed instructions.

2.3.1. Control group (only vigilance task)

Participants were instructed to identify a vertical pattern of lines by pressing a red button (“m” on the keyboard). In addition, they were informed that they would also see word phrases and a square with a number in the centre of the screen. It was explained that these additional stimuli were used in another condition and they would not be requested to do any task with these stimuli during the current study. Next, participants were engaged in the first practice session that required responding only to vertical lines. They were then informed that during the computer task they might experience different kinds of thoughts, and they were provided with examples of such thoughts, including personal goals, words, current concerns, plans, and memories. However, no particular emphasis was put on memories during the briefing. Participants were only told that memories could be diverse (i.e., specific, general) and pertain either to recent or remote past events. The participants were asked to report any spontaneous thoughts (regardless of what it was, or how interesting they found it to be) by pressing the spacebar as soon as they became aware of them. Next, they performed the second practice session.

After completing the second practice session, participants started the main vigilance task. Each time they pressed the spacebar, they were asked to provide a brief description of the content of their thoughts by typing it into the computer program. They also rated (by ticking the answer in the program) to what extent they had deliberately tried bringing the thought to mind (1 = *I wasn't trying at all*, 2 = *I wasn't trying*, 3 = *I don't think I tried*, 4 = *I tried a little bit*, 5 = *I tried somewhat*, 6 = *I tried*, 7 = *I tried very hard*).[5] This online rating procedure was deliberately brief in order not to interfere with the main vigilance task. After completing the questions, participants clicked ‘continue’ to return to the vigilance task. Halfway through the computer task (after 400 cards), participants had to answer additional control questions by rating the extent to which they had been concentrating on computer task as a whole (1 = *not concentrating at all*, 4 = *somewhat concentrating*, 7 = *fully concentrating*), the difficulty of the computer task as a whole (1 = *not difficult at all*, 4 = *somehow difficult*, 7 = *extreme difficult*), and the importance of performing the computer task as well as they could (1 = *not important at all*, 4 = *somewhat important*, 7 = *extremely important*). Following this, they returned to the vigilance task.[6]

At the completion of the vigilance task, participants answered open-ended questions concerning what they thought was the true goal of the study. Next they responded to additional manipulation-check questions by rating the extent to which they had been concentrating on the verbal phrases (1 = *not concentrating at all*, 4 = *somewhat concentrating*, 7 = *fully concentrating*), the difficulty of the computer task (1 = *not difficult at all*, 4 = *somewhat difficult*, 7 = *extreme difficult*), the importance of performing the computer task as well as they could (1 = *not important at all*, 4 = *somewhat important*, 7 = *extremely important*), and their level of fatigue (1 = *not tired at all*, 4 = *somewhat tired*, 7 = *extremely tired*). They were then provided with written and verbal instructions describing the nature of autobiographical memory (as, for example, in Schlagman, Kliegel, Schulz, & Kvavilashvili, 2009, p. 410) and informed about the next part of the study. During this part, participants reviewed all of their mental contents recorded earlier, one at a time and in the same order as they had been recorded. Participants were instructed to decide whether each thought was an autobiographical memory or not by clicking the ‘start’ button (if it was) or the ‘next’ button (if it was not). After clicking the “start” button, they were asked to describe the memory more thoroughly by typing it into the computer program. At the completion of the IMP, they filled in the Social Desirability Scale (Drwal & Wilczyńska, 1980)[7] and the Beck Depression Inventory (Parnowski & Jermajczyk, 1977).

[4] The Polish adaptation of verbal phrases is described in detail elsewhere (Barzykowski & Niedźwieńska, 2016, p. 6).

[5] As it was highlighted elsewhere (e.g. Barzykowski & Niedźwieńska, 2016, pp. 6–7): “this scale reflects participants' confidence in their introspective judgment of effort. So, as the numbers increase from 3, the participants are less confident that no effort was involved”.

[6] Please note that all participants could rest for a while during the online rating which limited the risk that after a certain point participants would stop reporting any mental contents due to tiredness and the task burdensomeness. This may be especially important in the cognitive load condition that was far more demanding.

[7] This way, as it was also done by Schlagman and Kvavilashvili (2008), we wanted to control for the possibility that participants tried to deliberately recall mental contents to please the experimenter. This questionnaire consists of 29 items of the „true-false” type. The reliability coefficients (internal consistency and stability) for the questionnaire equalled 0.79–0.90. High coefficients of correlation (up to 0.82) with Marlowe-Crowne's scale (Crowne & Marlowe, 1960) were also obtained (Drwal & Wilczyńska, 1980).

Table 1
Means and standard deviations for variables measuring concentration, motivation, fatigue and mood across two groups.

	Study 1							Study 2						
	Group Control		Cognitive load					Group Control		Cognitive load				
	M	SD	M	SD	*t*	*p*	*d*	M	SD	M	SD	*t*	*p*	*d*
Social Desirable Scale	15.13	4.36	13.70	4.63	1.14	0.259	0.32	13.33	5.16	13.44	4.89	0.07	0.941	0.01
Beck Depression Inventory	8.42	6.19	6.87	4.70	1.05	0.300	0.28	7.68	4.06	6.92	4.78	0.061	0.547	0.01
Concentration on the computer task[a]	5.09	1.16	5.36	0.99	0.88	0.386	0.25	4.86[a]	1.01	5.88[a]	0.82	4.10	< 0.001	1.12
Concentration on verbal phrases	4.87	1.82	4.52	1.53	0.72	0.473	0.21	4.61	1.34	4.50	1.61	0.27	0.791	0.07
Importance of performing the computer task well[a]	5.23	1.19	4.96	1.24	0.75	0.457	0.22	5.71	0.81	5.96	0.82	1.11	0.271	0.31
Importance of performing the computer task well in retrospection	5.41	1.02	5.46	1.02	0.16	0.875	0.05	5.29	1.12	5.69	0.97	1.42	0.161	0.38
The level of fatigue	4.78	1.48	4.56	1.36	0.54	0.589	0.15	4.32	1.44	4.15	1.16	0.47	0.641	0.13

Means with the same subscripts are significantly different between columns within the same study.
[a] Online ratings.

2.3.2. Cognitive load group (vigilance task + a number-square task)

The only difference between the cognitive load condition and the control group was that participants were asked to perform a cognitively-loading parallel task. Every time the square in the centre of the screen turned green, participants had to decide whether the number in the centre of the green square was equal to the number of blue lines (range: 2–8) displayed on the screen. They pressed a green button for YES ("z" on the keyboard) or a black button for NO ("c"). One hundred and eighty critical trials with green squares were randomized. They appeared approximately once every 8 s (i.e. approximately every 4 cards) and featured equal numbers of YES and NO trials.

2.4. Results

For all statistical tests, reported below, the rejection level was set at 0.05 (unless otherwise specified), and the effect size was measured by Cohen's *d* with small, medium, and large effects defined as 0.2, 0.5, and 0.8, respectively (Cohen, 1988). None of the participants reported having guessed the real purpose of the study.

2.4.1. Equivalence of experimental groups

To test the comparability of experimental groups, the overall participants' means for the Social Desirable Scale (SDS), the Beck Depression Inventory (BDI), the importance of performing the computer task well (both online and retrospective ratings), the fatigue level, the concentration on the computer task (online ratings) and verbal phrases (retrospective ratings) were analyzed in a series of independent *t*-tests.

As can be seen in Table 1, no differences were observed between the two groups on any of these variables. Therefore, we argue that any possible differences between groups in the frequency of IAMs should not be due to group differences in the level of concentration, motivation, or fatigue.

2.4.2. Manipulation check

We conducted a series of independent *t*-tests on the mean ratings of the immediate and retrospective perception of the task difficulty to investigate whether the experimental manipulation was sufficient to cognitively load the participants. As expected, participants in the cognitive load group rated (online) the computer task as more difficult ($M = 2.88$, $SD = 0.88$) compared to the control condition ($M = 1.82$, $SD = 0.66$), $t = 4.61$, $d = 1.36$. The groups did not differ in the retrospective ratings. At the same time, the high level of performance on the square decision task in the cognitive load group (proportion of correct responses: $M = 0.82$, $SD = 0.08$) suggested that participants were really absorbed in this additional cognitive task.

Since we observed high performance on the second task and expected differences between the groups in how the participants perceived task difficulty, it can be reasonably argued that we successfully manipulated the level of cognitive load (low vs. high) between the experimental conditions.

2.4.3. Strategy for data analysis

The results of 6 participants who had < 50% of correct responses on either the vertical lines task or the square decision task were excluded from further analysis. Two independent judges read all thoughts recorded by the participants and assessed which of them were autobiographical memories. All entries identified by the participants as autobiographical memories were identified as such by the judges. However, some of the thoughts indicated as autobiographical memories by the judges were not identified as such by the participants.[8] Therefore, re-evaluated entries with an agreement of 100% were included in the analysis. Such entries (e.g. *having romantic dinner and intercourse with my partner last week, the first time I went to scout camp with people with special needs and disabilities, memory of me having a cycling accident, memory of my holidays in Egypt* etc.) accounted, on average, for 6% of all mental contents recorded by the participants.

Memories rated from 1 to 3 on the effort scale were considered involuntary autobiographical memories (Barzykowski & Staugaard, 2016). A rating of 4 (the middle of the scale = some effort) was inconclusive and therefore those memories were excluded, together with all memories that were rated > 4. We calculated the mean number of involuntary autobiographical memories (IAMs), the mean number of other mental contents reported (non-IAM contents), and the IAMD index for each participant. IAMD index was the proportion of involuntary autobiographical memories to the total number of all mental contents reported by a given individual and was calculated as follows: IAMD = Number of IAMs/(Number of IAMs plus Number of non-IAM contents).

Participants' values of 2.5 SD or more above or below the mean of the group on any of the variables were excluded. We conducted a series of independent *t*-tests for differences between groups. In total, we performed 4 *t*-tests in each study. To control for multiple comparisons, we chose the False Discovery Rate correction (Benjamini & Hochberg, 1995). With $\alpha = 0.05$, the critical value q was 0.38 in Study 1 and 0.50 in Study 2.

2.4.4. Number of non-IAM contents and IAMs

The participants' overall mean number of recorded non-IAM contents and IAMs were entered into a series of independent *t*-tests (see Fig. 1). The control group reported more non-IAM contents

[8] Due to the software usage, the decision whether a thought was a memory was irreversible which may have resulted in some errors the participants committed in the categorization task. In addition, since participants were asked to provide a detailed description only for memories, they knew that the more memories they had the longer the experiment would last. As the categorization task was performed at the very end of the experiment, this may have also affected their decisions at the categorization task.

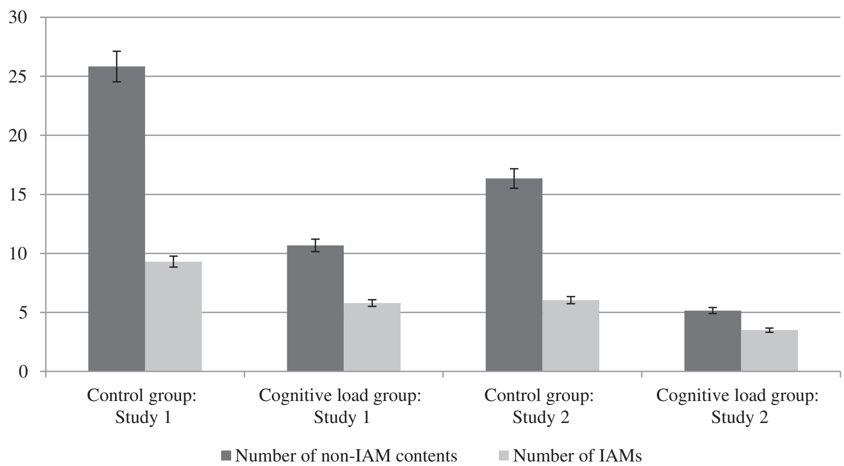

Fig. 1. The overall means of non-involuntary-autobiographical-memory contents (non-IAM contents) and involuntary autobiographical memories (IAMs) across groups. Error bars indicate 95% confidence intervals for the comparison groups.

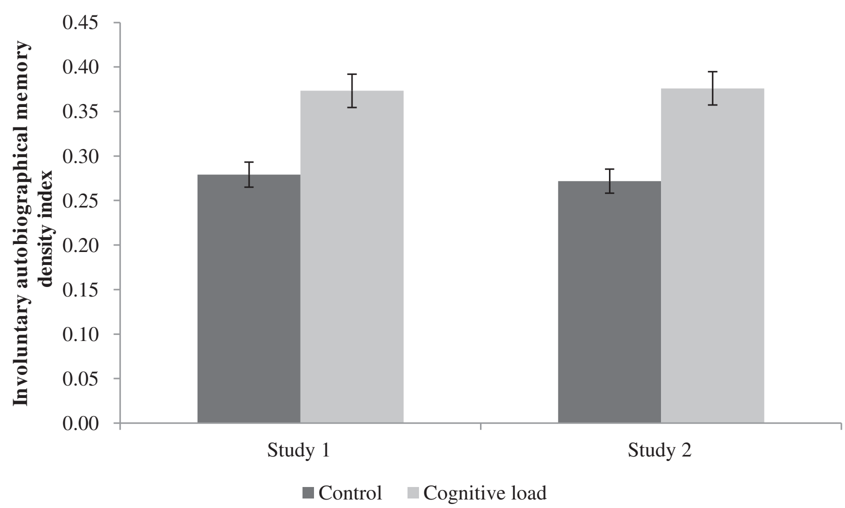

Fig. 2. The overall means of involuntary autobiographical memory density index across groups. Error bars indicate 95% confidence intervals for the comparison groups. Please note that IAMD index was the proportion of involuntary autobiographical memories to the total number of all mental contents reported by a given individual and was calculated as follows: IAMD = Number of IAMs/(Number of IAMs plus Number of non-IAM contents).

($M = 25.83$, $SD = 18.47$) compared to the cognitive load group ($M = 10.68$, $SD = 9.69$), $t = 3.51$, $d = 1.05$. Similarly, the control group reported more IAMs ($M = 9.30$, $SD = 6.46$) compared to the cognitive load group ($M = 5.80$, $SD = 4.95$), $t = 2.12$, $d = 0.61$.

The number of non-IAM contents and IAMs was not related to participants' social desirability scores in either control ($r_{non\text{-}IAM\ contents} = 0.03$, $p = 0.91$, $r_{IAMs} = -0.18$, $p = 0.42$) or cognitive load group ($r_{non\text{-}IAM\ contents} = 0.19$, $p = 0.37$, $r_{IAMs} = 0.27$, $p = 0.19$).

2.4.5. *Involuntary autobiographical memory density index*

The overall means of the IAMD index were entered into an independent *t*-test (see Fig. 2). The cognitive load group had a higher IAMD index ($M = 0.37$, $SD = 0.17$) compared to the control group ($M = 0.28$, $SD = 0.12$), $t = 2.19$, $d = 0.61$.

2.5. *Discussion*

To verify the presumed cognitive dependency of reporting IAMs, we provided half the participants with the cognitively-demanding secondary task. We expected that if reporting IAMs depends on cognitive load then they should be less frequently observed in the group with the secondary task compared to the control group. The differences between the groups in the number of non-IAM contents and IAMs accorded well with this expectation. At the same time, the differences between the groups in the IAMD index were in opposite direction; namely, IAMs were proportionally more frequently reported under cognitive load.

3. Study 2

The aim of Study 2 was to replicate the results of Study 1 by engaging participants in an even more cognitively-demanding task than the task used in Study 1. By doing so we wanted to provide additional evidence for the hypothesis that cognitive load may modify the frequency of reporting IAMs. We were especially interested in replicating our new and unexpected finding from Study 1 that cognitive load increases the relative frequency with which IAMs are reported. We increased the level of the task difficulty by doubling the number of the square-number decisions to be made. We expected to observe the same pattern of results as in Study 1; namely, a higher number of IAMs and non-IAM contents in the control group compared to the cognitive load group and a reversed pattern for the involuntary autobiographical memory density index, indicating more frequent IAMs in the pool of all spontaneous mental contents in the cognitive load group compared to the control group.

3.1. *Participants and method*

A total of 61 undergraduate students were recruited and randomly assigned to the two experimental conditions: the cognitive load condition and the control condition. They were all screened for depression using the Polish version of the Beck Depression Inventory (Parnowski & Jermajczyk, 1977). Four participants who scored 20 or above were excluded from the sample. Due to technical difficulties, three more participants did not finish the experiment. Therefore, the final sample consisted of 26 participants in the cognitive load condition (17 females, M_{age} = 21.73, SD = 1.73, range 19–25 years) and 28 participants in the control condition (18 females, M_{age} = 21.36, SD = 1.63, range 19–25 years). Students participated in return for course credit.

The procedure was the same as in the Study 1. Participants were either instructed (the cognitive load condition) or not instructed (the control condition) to perform the square decision task, in which they had to decide whether the number in the center of the green square was equal to the number of blue lines displayed on the screen. The only difference between Study 1 and Study 2 was that participants had to make twice as many decisions compared to Study 1. Three hundred and sixty critical trials appeared approximately once every 4 s (i.e. approximately every 2 cards) and featured equal numbers of YES and NO trials.

3.2. Results

3.2.1. Equivalence of study groups

We investigated the comparability of research groups the same way as in Study 1. The results presented in Table 1 show that the groups differed only in terms of concentration on the computer task (online ratings); namely, participants in the cognitive load group rated their concentration higher compared to the control group. However, we did not observe any other differences between the conditions. Therefore, we argue that groups were still comparable and any differences in the frequency of IAMs could not be explained by reference to the level of motivation, fatigue, or concentration on verbal phrases.

3.2.2. Manipulation checks

Similarly to Study 1, we compared the level of cognitive load between the conditions. By doubling the number of the square-number decisions to be made (compared to Study 1), we intended to increase the difficulty of the secondary task. The results of t-tests showed that the groups indeed differed significantly in this respect. In line with our expectations, participants in the cognitive group rated the task online as more difficult (M = 3.00, SD = 1.06) compared to the control group (M = 1.96, SD = 1.04), t = 3.63, d = 0.99. Similarly, the cognitive load group rated the task retrospectively as more difficult (M = 3.38, SD = 1.02) compared to the control group (M = 2.36, SD = 1.13), t = 3.50, d = 0.96. Similarly to Study 1, the high level of performance on the square decision task in the cognitive load group (proportion of correct responses: M = 0.85, SD = 0.11) suggested that participants were really absorbed by the secondary task.

These results lend support to the notion that our experimental manipulation was an effective way of engaging participants in the cognitive activity that increased cognitive load. The effect of experimental manipulation was stronger in Study 2 compared to Study 1 since the differences in the perceived task difficulty were observed in both online and retrospective ratings.

3.2.3. Number of non-IAM contents and IAMs

We entered the participants' overall mean number of recorded non-IAM contents and IAMs into a series of independent t-tests (see Fig. 1). The control group reported more non-IAM contents (M = 16.35, SD = 12.83) compared to the cognitive load group (M = 5.16, SD = 4.10), t = 4.23, d = 1.23. Similarly, the control group reported more IAMs (M = 6.04, SD = 4.35) compared to the cognitive load group (M = 3.50, SD = 3.25), t = 2.40, d = 0.67.

The number of non-IAM contents and IAMs was not related to participants' social desirability scores in either control ($r_{non\text{-}IAM\ contents}$ = − 0.05, p = 0.83, r_{IAMs} = 0.07, p = 0.75) or cognitive load group ($r_{non\text{-}IAM\ contents}$ = − 0.28, p = 0.22, r_{IAMs} = − 0.37, p = 0.10).

3.2.4. Involuntary autobiographical memory density index

We entered the overall means of the IAMD index into an independent t-test (see Fig. 2). The cognitive load group had higher IAMD index (M = 0.38, SD = 0.22) compared to the control group (M = 0.27, SD = 0.13), t = 2.07, d = 0.61.

3.3. Discussion

By providing participants with a more cognitively-demanding task, we wanted to examine whether the results of Study 1 could be replicated under slightly different conditions. We were indeed able to replicate findings from Study 1. The pattern of group differences for the number of non-IAM contents and IAMs was in line with the cognitive load dependency view. At the same time, the IAMD index showed that IAMs were proportionally more frequently experienced under cognitive load.

4. General discussion

In two experiments, we investigated the effect of cognitive load on the frequency of reporting IAMs. Participants were divided into two experimental groups: the control group (low cognitive load) and the cognitive load group with an additional demanding task. This allowed us to directly manipulate participants' effort needed to perform the ongoing task when retrieving IAMs. We calculated the mean number of IAMs and the mean number of other mental contents (non-IAM contents) provided by each participant, as well as the involuntary autobiographical memory density (IAMD) index. The index represents the proportion of IAMs in a pool of all mental contents reported by the participant. We hypothesised, in accordance with the cognitive load dependency view, that the frequency of reporting IAMs, as measured by both the number and the IAMD index, would decrease as cognitive load increased.

As expected, the number of non-IAM contents and IAMs was lower among the cognitively loaded participants compared to the control group in both experiments. However, the differences between the groups in terms of the IAMD index were in the opposite direction. Unexpectedly, but consistently across the two experiments, IAMs constituted a higher proportion of mental contents recorded by the participants in the cognitive load group compared to the control group. Put differently, participants indeed reported more IAMs when they were engaged in an activity with low cognitive resource demands. At the same time, it was more likely that mental content reported by someone engaged in a highly-demanding activity was an involuntary autobiographical memory.

4.1. Cognitive load dependency of reporting non-IAM contents and IAMs

4.1.1. The number of involuntary autobiographical memories and other mental contents

Our finding of a smaller number of IAMs and non-IAM contents in the cognitive load conditions accords with the literature on mind-wandering, which shows a decrease of thoughts as cognitive load increases (McKiernan et al., 2006; Singer, 1993). The same pattern was also observed for the number of IAMs in diary studies (e.g. Berntsen, 1996), and it accords very well with results by Vannucci et al. (2015). Our results may indicate that the number of non-IAM contents and IAMs was significantly hampered by the parallel task. Importantly, across both studies cognitive load led to the stronger decrease in the number of non-IAM contents (Cohen's d_1 = 1.03 and d_2 = 1.12 for Study 1 and 2 respectively) compared to the decrease in the number of IAMs (Cohen's d_1 = 0.61 and d_2 = 0.67), which may suggest that reporting IAMs are less cognitive load-dependent than reporting other types of spontaneous thoughts. The pattern of results may be related to the fact that non-IAM thoughts recorded by the participants referred to all types of mental contents (e.g. semantic knowledge, future thoughts, thoughts about a current situation) whereas IAMs referred only to self-relevant contents from the participant's personal past. If the involuntary retrieval of autobiographical events is more resistant to the effects of cognitive load compared to the involuntary retrieval of other types of information this may suggest that these processes draw on different resources.

It may also be that cognitive load somehow modifies the information that is available to consciousness by boosting the likelihood that IAMs will pass the awareness threshold. For example, cognitively loaded participants may just notice highly activated contents, whereas contents with low accessibility and a low level of activation may go unnoticed (Barzykowski & Niedźwieńska, 2016; Barzykowski & Staugaard, 2017). As a result, an increase in cognitive demands may more strongly undermine participants' ability to notice and report thoughts that are not autobiographical memories, as memories are more self-relevant and therefore presumably more accessible.

4.1.2. The involuntary autobiographical memory density index

Our finding of IAMs being proportionally more often reported by the cognitively loaded participants suggests that cognitive load may play an important though unexpected role in the formation of IAMs. It appears that cognitive load does not limit reporting IAMs as much as it limits reporting non-IAM contents, which suggests that IAMs may be more automatically retrieved than other spontaneous thoughts. Actually, a recent study by Plimpton, Patel, and Kvavilashvili (2015) lends support to the notion that IAMs are more automatic (i.e. less dependent on cognitive load) and more accessible than other thoughts. They found that when spontaneous thoughts were recorded by participants during a vigilance task, the frequency of IAMs was significantly greater compared to both thoughts about the future and thoughts about a current situation. Importantly, the last two types of spontaneous thoughts did not differ from each other in frequency.

4.2. Possible limitations and alternative explanations

We suggest that the pattern of results (i.e. a smaller decrease in the number of IAMs, compared to non-IAM contents, due to cognitive load and the higher proportions of IAMs under cognitive load) indicates that reporting IAMs is less cognitive load-dependent and IAMs are more accessible than other types of spontaneous thoughts. The question is whether any aspect of our procedure or results imposes constraints on this interpretation.

First, it may be suggested that performing a parallel task reduces the time in which participants may report IAMs during the ongoing task (Berntsen, 2009, p. 97; for reference to involuntary thoughts see also: Schooler et al., 2011) and attend to potential cues. This may explain the reduced number of non-IAM contents and IAMs in the cognitive load condition compared to the control condition. However, taking this issue into account, we used the proportion of IAMs in a pool of all thoughts recorded as a measure of frequency of IAMs and actually found that it increased from the control condition to the cognitive load condition. It is rather unlikely that having less time for recording thoughts and attending to cues differentially influenced various types of thoughts (e.g., having smaller impact on recording autobiographical memories compared to other types of thoughts).

Second, it may be suggested that cognitively loaded participants intentionally limited their recording of some types of mental contents more than others. However, it is rather unlikely that participants were inclined to limit their reports only in respect to some types of mental content. In both the cognitive load and control condition, participants were uniformly instructed to write down any kind of mental thought that would arise during the vigilance task, regardless of what it was, or how interesting they found it to be. By doing so, we tried to prevent the participants from using a layperson's definition of spontaneous mental contents and to reduce the extent to which they might voluntarily limit their responses only to some types of memories or thoughts (see also Barzykowski & Niedźwieńska, 2016).

Third, since our goal was only to examine the presumed cognitive dependency of reporting IAMs, we decided to use self-caught method. More importantly, this procedure was also used in studies of Vannucci et al. (2015), Ball (2007) and naturalistic diary studies. However, as the self-caught measure relies on meta-awareness, it is unclear whether cognitive load influenced the retrieval processes of IAMs (e.g. forming and developing an involuntary memory) or/and the post-retrieval processes (e.g. the ability to monitor the flux of awareness for involuntary autobiographical contents). Therefore, it is still not clear whether the retrieval of IAMs is more resistant to the effects of cognitive load compared to the retrieval of non-IAM contents or whether IAMs are more salient and hence more likely to be noticed under conditions that challenge the ability to monitor the stream of thoughts. These issues still need to be addressed in future studies using a probe-caught method in which participants are randomly stopped during the vigilance task and asked what was going through their mind at the exact moment they were stopped (see Plimpton et al., 2015). Compared to the self-caught method, the probe-caught method substantially diminishes requirements for continuous monitoring the flux of awareness and extracting content of thoughts from the stream. Participants are prompted to do that only at certain moments. If our results are replicated with the probe-caught method, it would more directly imply the effect of cognitive load on the retrieval rather than post-retrieval processes. While our study does not provide this information, it does not weaken our main findings which pertain to the frequency of reporting IAMs under different cognitive load conditions.

Fourth, it can be argued that our results rely on retrospection, i.e. participants were asked to carry out the thought monitoring process at the very end of the session. In other words, it may be difficult for participants to decide retrospectively with great precision whether thoughts recorded during the vigilance task were or were not about autobiographical events. However, it was done in the same way in previous studies (Vannucci et al., 2014), and participants did this classification relatively easily and quickly. Having only short thought descriptions they did not have any difficulties in identifying autobiographical memories among their recorded thoughts. In addition, all entries identified by participants as memories were coded as such by independent judges.

Finally, similarly to other studies on IAMs and spontaneous thoughts (e.g. Barzykowski & Niedźwieńska, 2016, 2017; Barzykowski & Staugaard, 2016, 2017; Vannucci et al., 2014), there were big variations in the number of spontaneous thoughts that participants reported, i.e. some participants reported many thoughts and others reported very few. This may be caused by the individual difference factors, such as susceptibility to fatigue (e.g. McVay & Kane, 2009; Teasdale et al., 1995), the strength of inhibition processes (e.g. Verwoerd & Wessel, 2007), memory sensitivity (Cornoldi, De Beni, & Helstrup, 2007) or even the ability to recognize an involuntary memory (Mace, Bernas, & Clevinger, 2014). However, it is very unlikely that big variations in the number of spontaneous thoughts that participants reported influenced the pattern of our results. First, the distributions of the number of IAMs and non-IAM contents did not substantially differ across the cognitive load and control conditions, except for a shift in data distribution clearly due to the experimental manipulation. In those rare cases where the homogeneity of variance assumption was not met, we used the unequal-variance *t*-tests. Second, we dichotomised participants into those with low and high number of spontaneous thoughts (according to median value, and also contrasting those from the first and fourth quartile) to investigate whether these groups differed in the proportion of IAMs reported (the IAMD index). The IAMD indexes were entered into a series of 2 Condition (cognitive load vs. control) × 2 Group (high number vs. low number of spontaneous thoughts) factorial analyses of variance (ANOVAs). We did not find any effect of Group, either alone or in interaction with Condition, in any of the experiments, all $p_s > 0.14$.

4.3. Final conclusions

Consistently across two experiments, and in contrast to our expectations, involuntary autobiographical memories were relatively more often reported and constituted a higher proportion of mental contents under high cognitive load. This may suggest that reporting IAMs is less cognitive load-dependent than reporting other spontaneous thoughts. Our findings are based on the use of involuntary autobiographical memory density index which seems to be an efficient measure of cognitive load-induced effects on involuntary autobiographical memories, especially when the dual-task paradigm is adopted to manipulate cognitive load.

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